Demand-Based Allocation of Police Patrols in a Public Safety Emergency Response System Using Discrete Stochastic Simulation

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Abstract

Our research focuses on assisting current operations of a public safety Emergency Response System (ERS) in a large city in Mexico to achieve the international ideal response time of three minutes maximum based on allocating the optimum number of police patrols. We believe that improvements in patrol response times will strongly improve statistics in the crime prevention and control as well as in the apprehension of presumable delinquents. The city is composed by eight police districts and this research integrates an additional district to four previously evaluated. In this research we first characterized the demand for service and processes linked to the attention of the call and patrol utilization. Next, we built a stochastic simulation model to reproduce current operating conditions to validate its behavior. Ultimately, we identified the optimum number of police patrols required to be allocated as back up inventory in each police quadrant within all districts.

Keywords

Patrol Allocation; Emergency Response Systems; Public Safety

Introduction

Even though public safety gradual improvements have been reported in the last two years, there still are alarming crime statistics in multiple regions in Mexico. Multiple global factors that require urgent international cooperation among governments seem to be influencing this social condition. However, society must claim its fundamental right to have a safe environment and actively participate in shaping it and peacefully defending it.

Attaining and preserving the public safety and well-being of society is an imperative function conducted by ERS (Zaki, Cheng, and Parker, 1997; Zhang and Brown, 2013). However, this function needs to be fulfilled offering acceptable service levels that satisfy public safety expectations (Adler et al., 2013). The key performance parameter for ERS is identified by Surkis, Gordon and Hauser (1970) as *response time,* which is defined as the time interval between answering a call for emergency service and the arrival of the unit to the location where it is required (D'Amico et al., 2002; Zaki el al., 1997 and Stevens et al., 1980).

This research extends former efforts of Holguin-De La Cruz (2013) incrementing the number of evaluated police districts from four to five out of a total of eight in the city. Equally, the objectives of this research include: (1) characterization of demand for service and service performance parameters, (2) modeling ideal present conditions identified as Basic Proposal scenario, (3) modeling scenario with 3 minutes maximum response time restriction (NACCJ, 1973), (4) identifying ideal patrol inventory levels for police quadrants, and (5) identifying areas of opportunity for improvement. In this research the commercial simulation software ProModel 7.0 was utilized.

The newly integrated district to this research is a neighbor to the south of the already integrated downtown district. This police district is densely populated and has on its west limit an unpopulated mountainous topography. The estimated population of the city is larger than 1.3 million inhabitants (INEGI, 2007) and it is established in a surface larger than 300 Km^2. The city's ERS provides data from 552 continuous hours where demand for service and response times are obtained from. Every police district is composed by four quadrants and every quadrant has four patrolling zones. Actual operating strategy requires one patrol for each patrolling zone of the 16 that integrate a police district. However, this allocation strategy is often not met due to limited resources.

Literature Review

The problem of identifying the optimum allocation of personnel and equipment capable of minimizing the response time to or under a specific value is well defined (Zaki el al., 1997). The disciplines of Operations Research and Management Sciences have traditionally contributed since the 1960's with prescriptive models supporting the decision making process related to improving the efficiency of emergency response systems (D'Amico et al., 2002; Green and Kolesar, 2004). However, Green and Kolesar (2004) identify new challenges to generate new operating strategies that may be useful in catastrophic events such as the 9/11 in N.Y. city. The traditional methodologies often used to address solutions to ERS performance include queuing models (Green and Kolesar, 2004), shortest path algorithm (Adler et al., 2013), hypercube model (D'Amico et al., 2002; Takeda et al., 2007), and stochastic simulation (Zaki et al., 1997; Brooks et al., 2011; Zhang and Brown, 2013, 2014; Wu et al., 2014). The standardized nomenclature to identify main activities within the ERS process has been presented in the literature (Maxfield, 1982; Zaki et al., 1997; and Green and Kolesar, 2004).

Methodology and Case Study

Our research integrates results of the 5th police district to the results of four districts previously evaluated. Typically, police districts are divided into four quadrants, and every quadrant is divided into four patrolling zones. However, sometimes districts of relative larger size are divided into five quadrants. The ideal patrolling strategy followed by the city's ERS allocates one patrol for every patrolling zone. Nevertheless, due to insufficient availability of resources this allocating strategy is only met 70% to 85% of the time on average. The simulation approach models individual police quadrants based on probability distributions of the demand for service and the service processes. On the other hand, due to the page limit of this article, results are presented by police district reflecting quadrants' averages.

This research considers two scenarios identified as BP-Actual and RT3M. The first scenario, BP-Actual, models actual operations based on the idealized concept that every patrolling zone has a dedicated patrol (Basic Proposal). The second scenario, RT3M, considers optimized and realistic dispatch and transportation times based on adequate allocation of resources. In addition to the four dedicated patrols within a quadrant, four back-up patrols, available by priority, are included in both scenarios to evaluate their usage as direct metric of the optimum number of back-up patrols to be allocated and be able to meet the reference response time of 3 minutes maximum to a given service level. These back-up patrols are available to attend a call-for-service if any dedicated patrol of a zone is busy attending another call.

Given our model's configuration and restrictions, every police quadrant integrates:

P_{dj} =Dedicated patrol d for patrolling zone j, d=1 to 4, and j=1 to 4, and

B_{ij} =Back up inventory patrol i assisting any patrolling zone j, i=1 to 4, and j=1 to 4

Back-up Patrol Usage Priority: $i=1 > i=2 > i=3 > i=4$

Since our ERS data corresponds to 552 continuous hours we decide to use the same amount of time to configure the model's running time; and every scenario is evaluated based on obtained results from averages of ten replications.

Results

We present the demand for service and main serving processes characterizations results integrating the 5th evaluated district to the previous results of the four analyzed districts. In Table 1 the characterization of parameters *Interarrival Time*, *Response Time* and *Patrol Busy Time at the Location of Event* are presented. From this table we can estimate that across districts, the *Interarrival Time* is primarily composed by Exponential (56%), Lognormal (18%), and Gamma (17%) probability distributions. Similarly, for the *Response Time* parameter, it is observed that the main probability distribution that describes it is Lognormal (78%). Lastly, for the parameter *Patrol Busy Time at Location*, the main probability distributions that describe it are Lognormal (40%), Exponential (32%), and Gamma (20%).

As an example of the service level provided for only urgent (Priority 1) calls in the 5th police district based on its CDF, we identify that the quadrants' averages show: (1) only 1.07% of the calls meet the 3 minutes maximum response time international reference, (2) 80% of the calls have a response time of 12.78 minutes maximum, (3) 95% of the calls have a response time of 20.24 minutes maximum, and (4) 99% of the calls have a response time of 30.33 minutes maximum.

TABLE 1 CHARACTERIZATION OF ARRIVALS AND SERVICE TIMES OF THE CITY'S ERS

Parameter	D_k[a]	Probability Distributions (95% C.I.)							Total
		Exponential	Gamma	Loglogistic	Lognormal	Normal J-T	Normal	Weibull	
Interarrival Time	D_1	30	9		7			2	48
	D_2	41	6		1				48
	D_3	27	6		9			6	48
	D_4	36			12				48
	D_5	1	21		14			12	48
Response Time	D_1			3	13	3		2	21
	D_2				12				12
	D_3		3		9				12
	D_4	1	1		9		1		12
	D_5		1		11				12
Patrol Busy Time at L[b]	D_1	6	4	3	7	1			21
	D_2	6	2		4				12
	D_3	4	1		7				12
	D_4	2	7		3				12
	D_5	4			7			1	12
Total		158	61	6	125	4	1	23	378

[a] = (D_k) Police District *k*

[b] = (L) Location of Event

Averages of the performance parameter *Average Number of Times Used (ANTU)* for back up patrols in the BP-Actual scenario of all five police districts are 51.1, 7.8, 2.3, and 1.6 respectively for B_{1j}, B_{2j}, B_{3j} and B_{4j}. Correspondingly, these averages for the RT3M scenario are 36.9, 4, 1.7, and 1.4 respectively for the same back up patrols. As observed, back up patrols in the RT3M scenario are less demanded since dedicated patrols have increased availability due to shorter dispatch and transportation times, which allows them to attend additional incoming calls for service.

Figure 1 illustrates a graphical representation of the *Average Number of Times Used (ANTU)* parameter. From this figure we observe that in general the *ANTU* parameter is increased for all dedicated patrols in the RT3M scenario and the opposite is identified for back up patrols. This is explained given the increased availability of the dedicated patrols since the RT3M scenario requires significantly smaller transportation and dispatch times, which directly decreases the frequency at which back up patrols are used.

Based on reported results, the optimum number of patrols based on the RT3M scenario for all districts could be derived from several criteria including: (1) use a back up patrol if it at least covers 1% of the observed events on average within a given time interval (23 days in this case), or (2) use a back up patrol if it at least serves 1 observed event on average within a time interval (23 days in this case). If the first criterion is used, the optimum allocation of patrols would be: District 1 (2), District 2 (1), District 3(1), District 4 (1), and District 5 (2). Similarly, if the second criterion is applied, we would need at least 4 back up patrols for each police district.

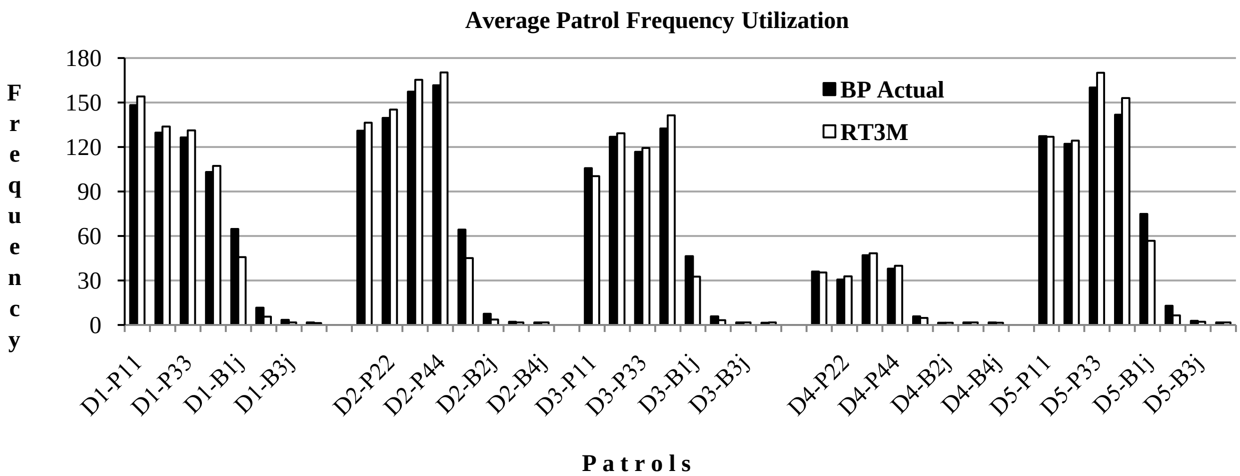

FIG. 1 AVERAGE FREQUENCY UTILIZATION BY PATROL FOR DISTRICTS D_1, D_2, D_3, D_4 AND D_5

Conclusions

Results provided by our stochastic simulation analysis generate a very useful transparency in terms of patrol utilization, which allows us to better understand the value added by every dedicated and back up patrol evaluated in every police quadrant of each analyzed police district. This condition is fundamental in the decision making process for the efficient allocation of patrols to be able to respond to performance parameters such as the response time reference of 3 minutes maximum.

We continue to identify through the geographical research of five police districts that recommended allocation levels of police patrols are attainable, which support the design-to-meet-requirement approach instead of the strategies that only optimize known insufficient resources. However, substantial efforts would have to be made to improve the dispatch and transportation processes, which can be the focus of additional researches.

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